

“MULTI-DISCIPLINARY ANALYSIS & OPTIMIZATION FRAMEWORKS”

**presented at the
Systems Analysis Design & Optimization (SAD&O) Technical Working Group
Meeting, Orlando, FL, January 2009**

Since July 2008, the Multidisciplinary Analysis & Optimization Working Group (MDAO WG) of the Systems Analysis Design & Optimization (SAD&O) discipline in the Fundamental Aeronautics Program’s Subsonic Fixed Wing (SFW) project completed one major milestone, “Define Architecture & Interfaces for Next Generation Open Source MDAO Framework” Milestone (9/30/08), and is completing the Generation 1 Framework validation milestone, which is due December 2008. Included in the presentation are: details of progress on developing the Open MDAO framework, modeling and testing the Generation 1 Framework, progress toward establishing partnerships with external parties, and discussion of additional potential collaborations.



Systems Analysis Design and Optimization (SAD&O) Technical Working Group (TWG) Meeting

Subsonic Fixed Wing Project NASA Fundamental Aeronautics Program

Six Month Status Update: Multi-Disciplinary Analysis & Optimization Frameworks

Cynthia Gutierrez Naiman

47th AIAA Aerospace Sciences Meeting
Orlando, FL

January 5, 2009



Topic Outline

- Brief Overview
- OpenMDAO Status
- Outreach
- Next Steps
- Conclusion

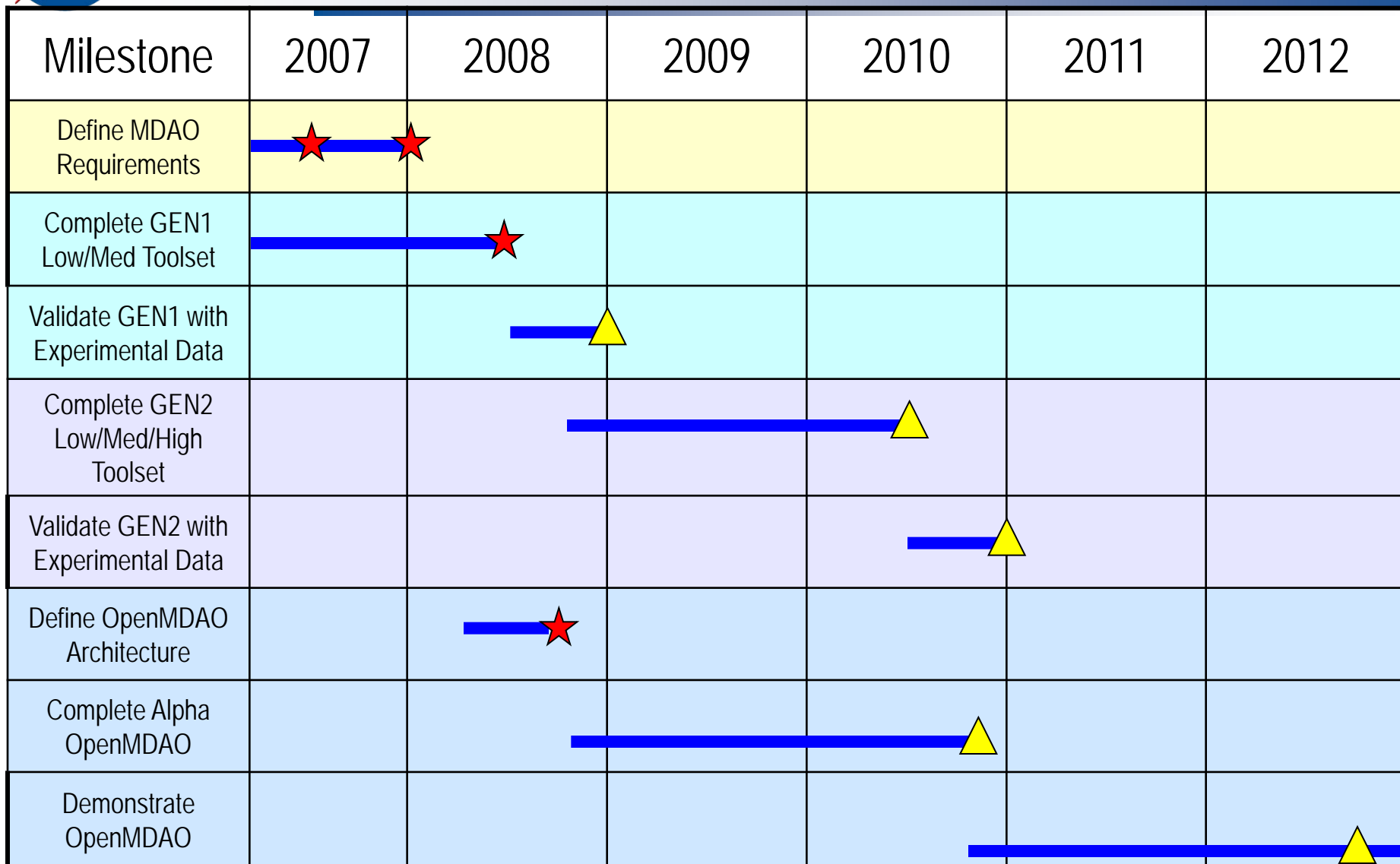


MDAO Task Goal & Objectives

- GOAL
 - Advance the state of the art of physics-based multidisciplinary analysis & optimization for both conventional & unconventional vehicles.
- OBJECTIVES
 - Focus on Subsonic Fixed Wing and Supersonics applications, but develop capabilities that can support all flight regimes.
 - Improve current MDAO tools and integration techniques.
 - Establish the groundwork and provide an open source next generation MDAO capability for far-term activities.
 - Collaborate with the MDAO community in industry, academia, and other government agencies throughout the development process to benefit all parties.



MDAO Milestone Roadmap



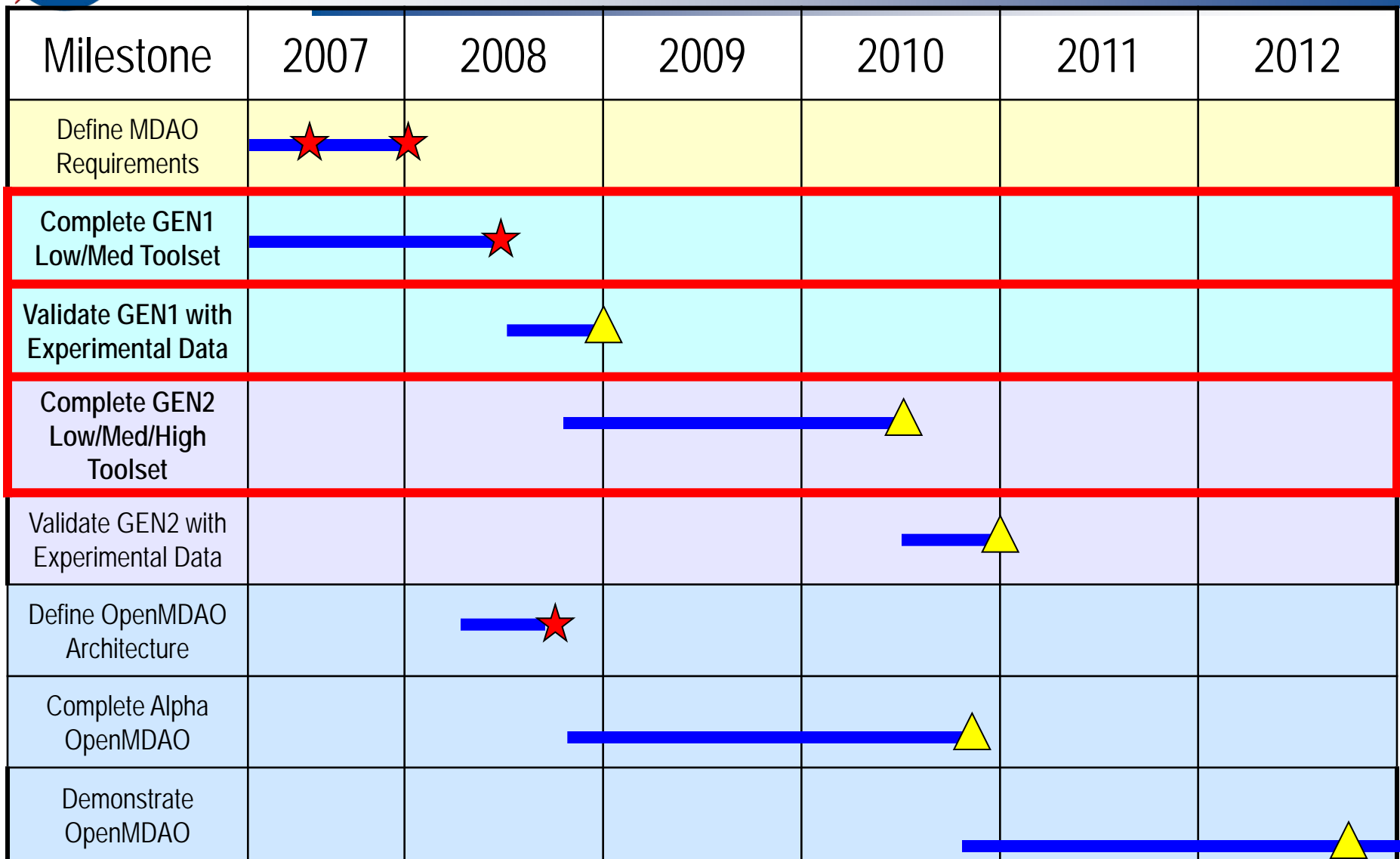
Completed Milestone

Timeline

Planned Milestone



MDAO Milestone Roadmap



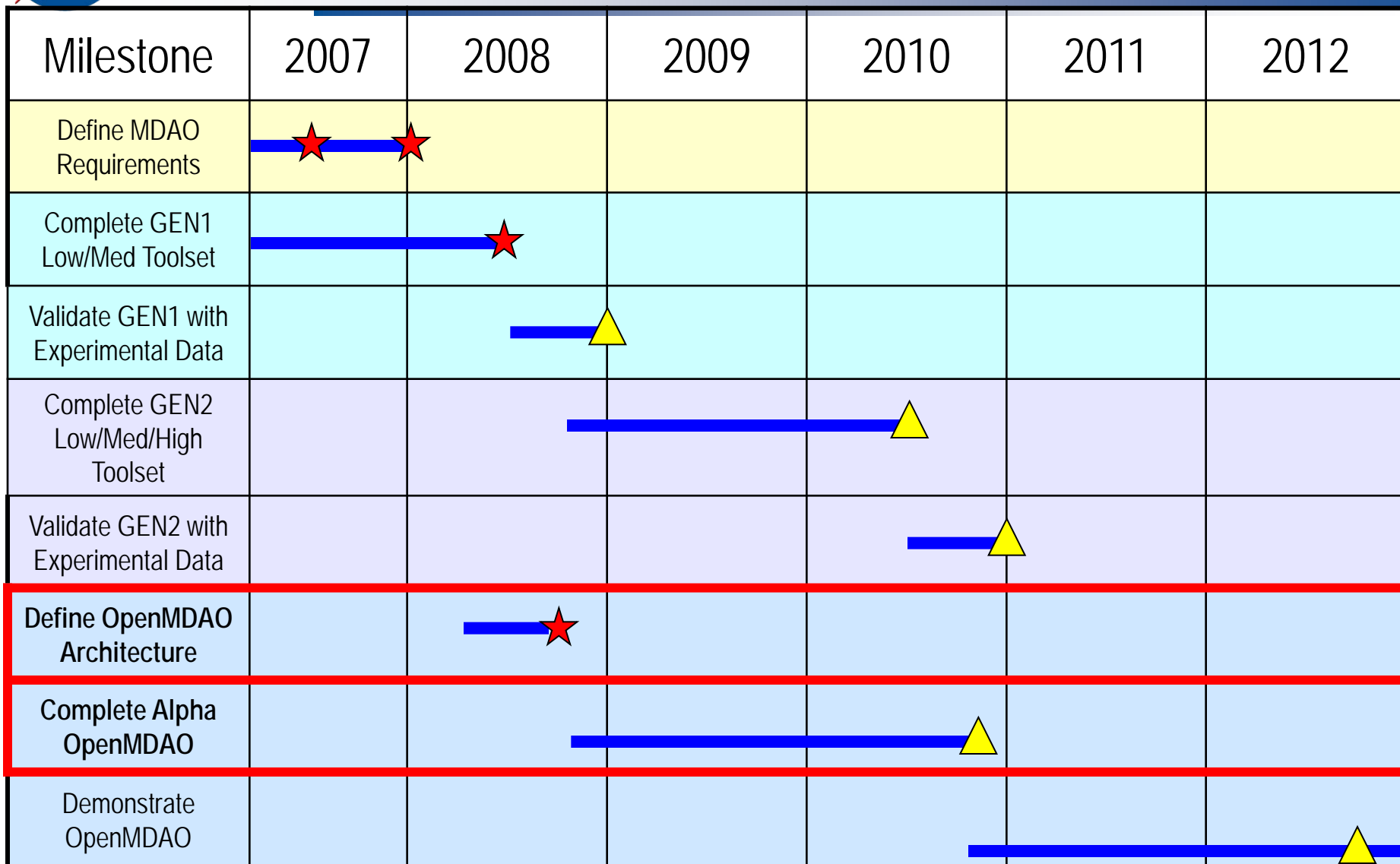
Completed Milestone

Timeline

Planned Milestone



MDAO Milestone Roadmap



Completed Milestone

Timeline

Planned Milestone



OpenMDAO Status Highlights

- Completed initial "[*Next Generation Open Source MDAO Framework Architecture Document*](#)" (9/30/08 milestone)
- Implementing core OpenMDAO framework objects using python
- Held python training at LaRC and scheduled another session at GRC
- Evaluating variable fidelity objects from M4 Engineering SBIR
- Implementing "[*toy*](#)" [*distributed simulation*](#) to learn about python distributed objects



OpenMDAO Status Highlights (continued)

- Prepared to request [Requirements feedback](#)
- Revisiting MDAO Test Cases (interfaces and testing)
- Researching what's needed to launch [OpenMDAO external website](#)
- Evaluating & setting up development tools (Bazaar, Trac) & [processes](#)



OpenMDAO Status Highlights (continued)

- Continuing to develop [Problem Formulation Prototype](#) using python
- Presented Papers at AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference in Victoria, CA :
 - *"The Development of an Open-Source Framework for Multidisciplinary Analysis and Optimization"* by Moore, Naylor, & Gray
 - *"Reliability Based Design Optimization of a Composite Airframe Component"* by Patnaik, Pai & Coroneos



Outreach: Collaboration

- Examples of parties who have indicated interest:
 - NASA (Constellation)
 - DoD
 - Computational Research & Engineering Acquisition Tools & Environments (CREATE) Program
 - AFRL: Air Vehicles & Propulsion Directorates
 - DoE
 - Sandia Labs: Design Analysis Kit for Optimization and Terascale Applications (DAKOTA)
 - Industry: Boeing, Lockheed, GE
 - Academia: Georgia Tech, Stanford, University of Toronto
- Example NRA & SBIR:
 - Subsonic Fixed Wing SBIR
 - Multidisciplinary Optimization Object Library (M4 Engineering)
 - Supersonics NRA
 - Control of Boundary Representation Topology in MDAO (MIT)



Outreach: Collaboration Ideas

- Requirements
 - Feedback on latest Requirements: suggest changes & additions
 - Propose additional Use Cases
- Testing
 - Test Cases
 - User feedback
 - Beta testers
- Identify areas of functionality to share & contribute
 - Geometry
 - Uncertainty Analysis
 - Optimization
 - Framework
 - Discipline codes



Outreach: Partnerships

- Identify partners interested in establishing Space Act Agreements or Interagency Agreements
- Follow-up with interested parties, establish agreements, and work as a group
- If your company/organization is interested in this MDAO activity, contact Cynthia Naiman



Next Steps

Sub Tasks	Activities	1Q FY09	2Q FY09	3Q FY09	4Q FY09
Requirements	•Document feedback on discipline requirements				
	•Allocate groupings of requirements to be completed by 4QFY10				
	•Identify, define, & document test cases				
GEN1 Validation	•Exercise GEN1 Capability for Commercial Transport				
	•Document validation results in GEN1 report				
GEN2 HWB Toolset	•Identify HWB configuration to use for 3QFY10 milestone				
	•Define GEN2 validation plan				
	•Determine what discipline codes are needed				
	•Identify which codes need to be integrated into ModelCenter				
	•Identify needed code improvements and/or integration techniques				
	•Implement code & integration improvements				



Planned Milestone



Timeline



Next Steps (continued)

Sub Tasks	Activities	1Q FY09	2Q FY09	3Q FY09	4Q FY09
Alpha OpenMDAO Framework	•Continue prototyping using python				
	•Offer python training				
	•Set up development environment				
	•Research what is needed to setup an open source project				
	•Setup technical infrastructure and communications mechanisms				
	•Define processes for daily development & release distribution				
	•Prepare website and documentation for open source public release				
	•Address export control & legal issues				
	•Implement core framework classes				
Outreach	•Solicit feedback on requirements from potential external partners				
	•Host meetings with interested parties (industry, academia, gov)				
	•Pursue potential collaboration in Open Source MDAO community				
	•Leverage NRA & SBIR MDAO efforts				
	•Present status at SAD&O Technical Working Group Meetings				



Conclusion

- Physics-based MDAO is a critical national need and is an extremely difficult challenge
- 2-Path approach benefits near- and long-term needs
- User involvement throughout the development life-cycle is critical
- Partnering with industry, academia, and other government agencies is essential to realize MDAO vision



Additional Information Available

- See SAD&O Website:
 - <http://mdao.grc.nasa.gov/SADO-TWG/index.html>
 - Userid "guest"
 - Password "sado"
- Contact Cynthia Naiman
 - Cynthia.G.Naiman@nasa.gov
 - 216-433-5238



"Toy" Simulation to Explore Distributed Object Communication

- Intended to provide semi-realistic environment for experimenting with different technologies.
- NOT intended as a prototype for the real framework, or something evolving into the real framework
- Supports typical data and process flows.
- Example problem is nested optimization of AXOD (AXial Off Design: a meanline axial turbine code that can generate off-design maps) input parameters to match a set of data.
- A genetic optimizer is used to set starting points for gradient optimizers distributed to nodes of local GX cluster.
- GX has 220 AMD Opteron (64-bit) processors connected via Infiniband running Debian Linux. It's local to GRC.
- Has experimental support for driving wxPython and web GUIs from the same GUI code.
- Matplotlib does the plotting.
- Distributed objects
 - Need support for distributing sub-models (for optimization, etc) as well as remote objects within a single model.
 - ['Twisted' package provides basic networking support for multiple protocols.](#) Twisted is a stable, widely used package. Twisted depends on various sub-packages like zope.interface, Crypto, OpenSSL. Twisted is used for HTTP, OpenSSL for HTTPS and RPyCS.
 - ['RPyC' package provides transparent support for distributed objects.](#) Not an exact fit for our requirements. RPyC is a new, evolving project. A modified RPyC does the distributed object communication.
- [Beginning to explore how M4 work can be incorporated into a framework similar to that defined in the architecture document.](#)
 - Numeric, numarray, numpy, scipy get pulled-in for M4 objects as well as matplotlib.



"Toy" Simulation



DesignAssistant Simulation ... x

http://gxterm3:9000/

Customize Links Free Hotmail Windows Media Windows Other bookmarks

DesignAssistant Simulation Manager

Simulation Help

Name	Host	PID	HTTP	HTTPS	RPyC	RPyCS	Manhole
AXOD_GAGR	gxterm3	16719	35197	46365	37259	57539	

Simulation Manager

The SimulationManager acts as a portal, allowing you to connect to existing simulations launch new simulations, and terminate simulations. This manager is running on the remote host gxterm3, which is a front-end to the GX cluster.

Next

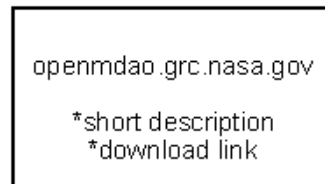


OpenMDAO Website Concept

Scenario 1:
The typical NASA open source website.

INSIDE NASA

OUTSIDE NASA



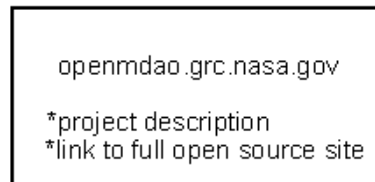
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Scenario 2:
(Desired)
Full open source community.

INSIDE NASA

OUTSIDE NASA



linked

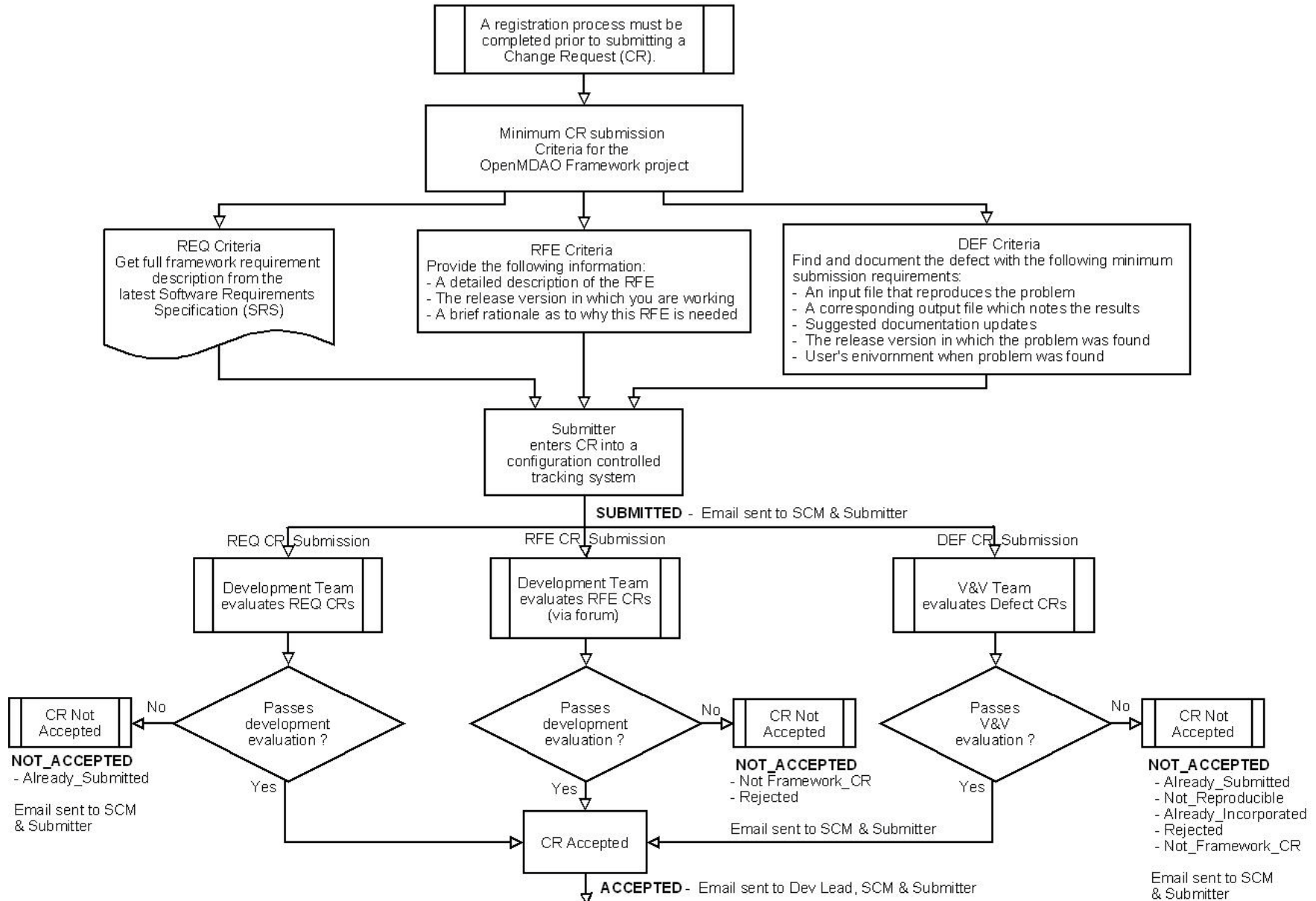


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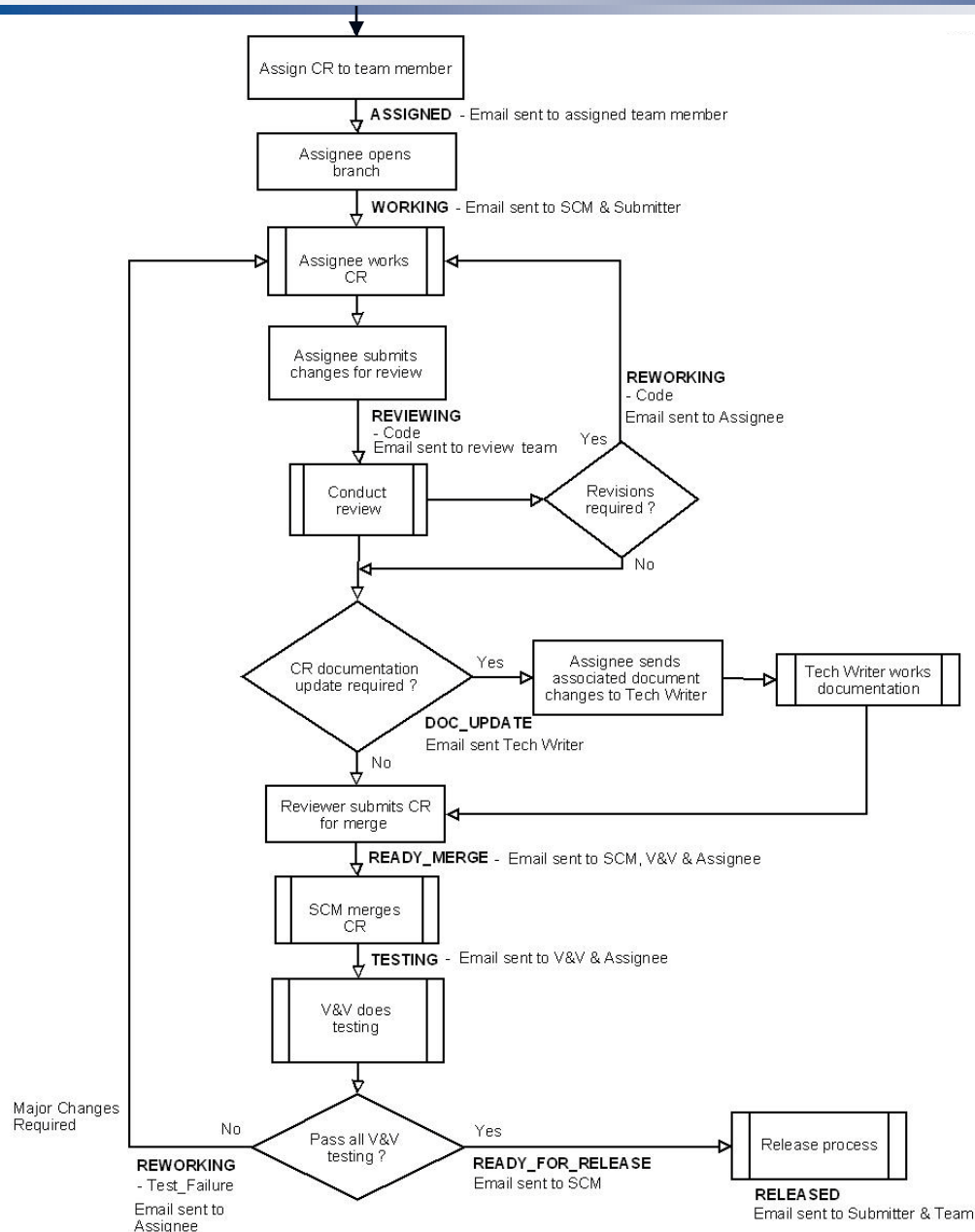


OpenMDAO Life Cycle Process



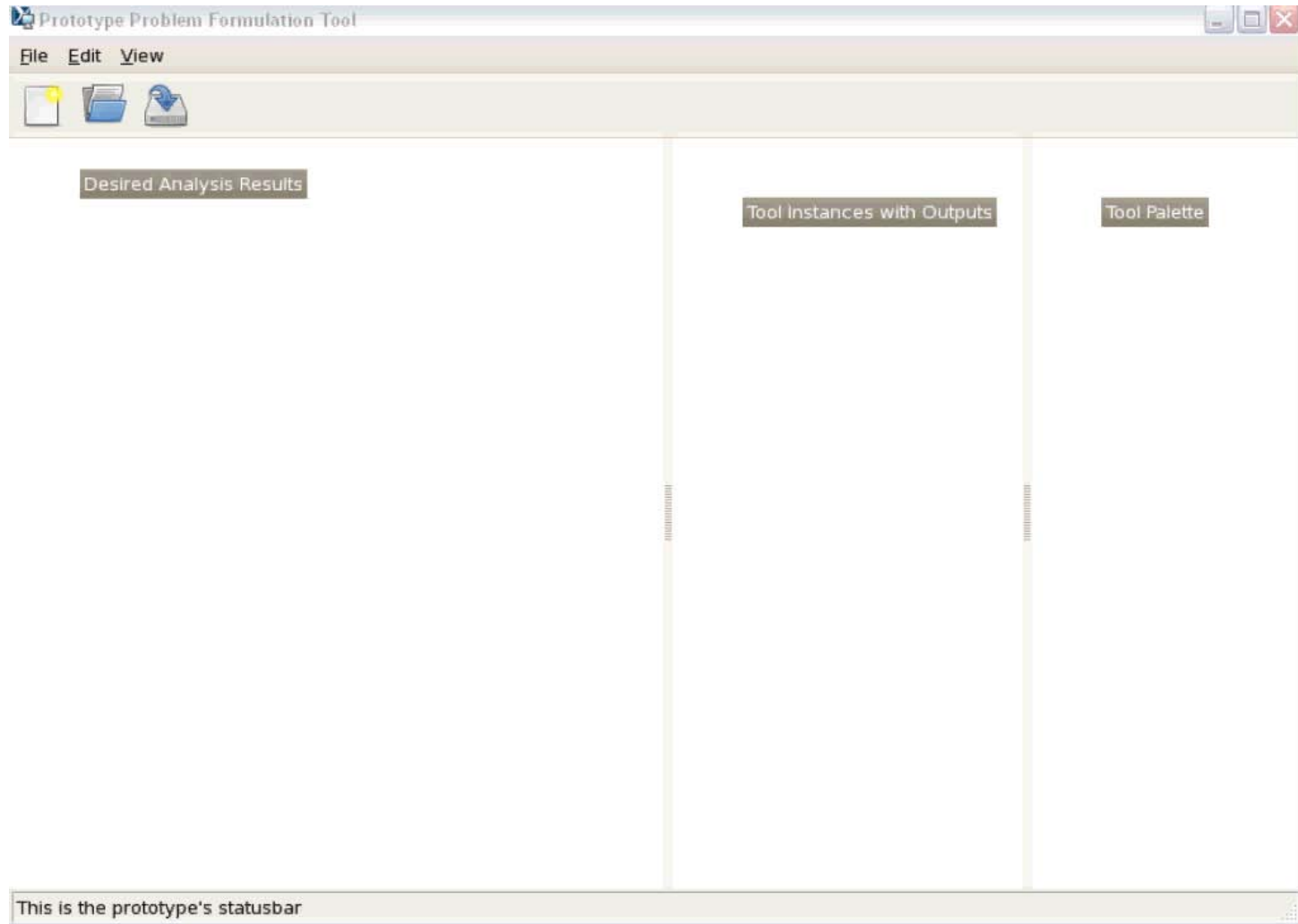


OpenMDAO Life Cycle Process (cont'd)





Problem Formulation Tool Prototype





Backup Charts



Role of OpenMDAO.org Website

- News/Information
- Source Code & Distributions
 - Read-only access to framework and open-source plug-ins to the general public
 - Changes to the framework come through NASA gatekeeper
 - Closed-source plug-ins (e.g. NPSS) have restricted access
 - Anyone can write a custom plug-in, and since it does not impact the framework source, it needn't go through a gatekeeper
 - Custom components and variable types that are written can be kept to oneself or shared with the community
 - Custom components that are shared could be rated by the community
 - Highly-rated custom components could be added to OpenMDAO standard lib
- Documentation
 - OpenMDAO User Guide
 - OpenMDAO Developer Guide
 - Use Case "How To" Guide
- Discussion Forums
- Submission of Defects
- Proposals for Enhancement
- Adding New Developers



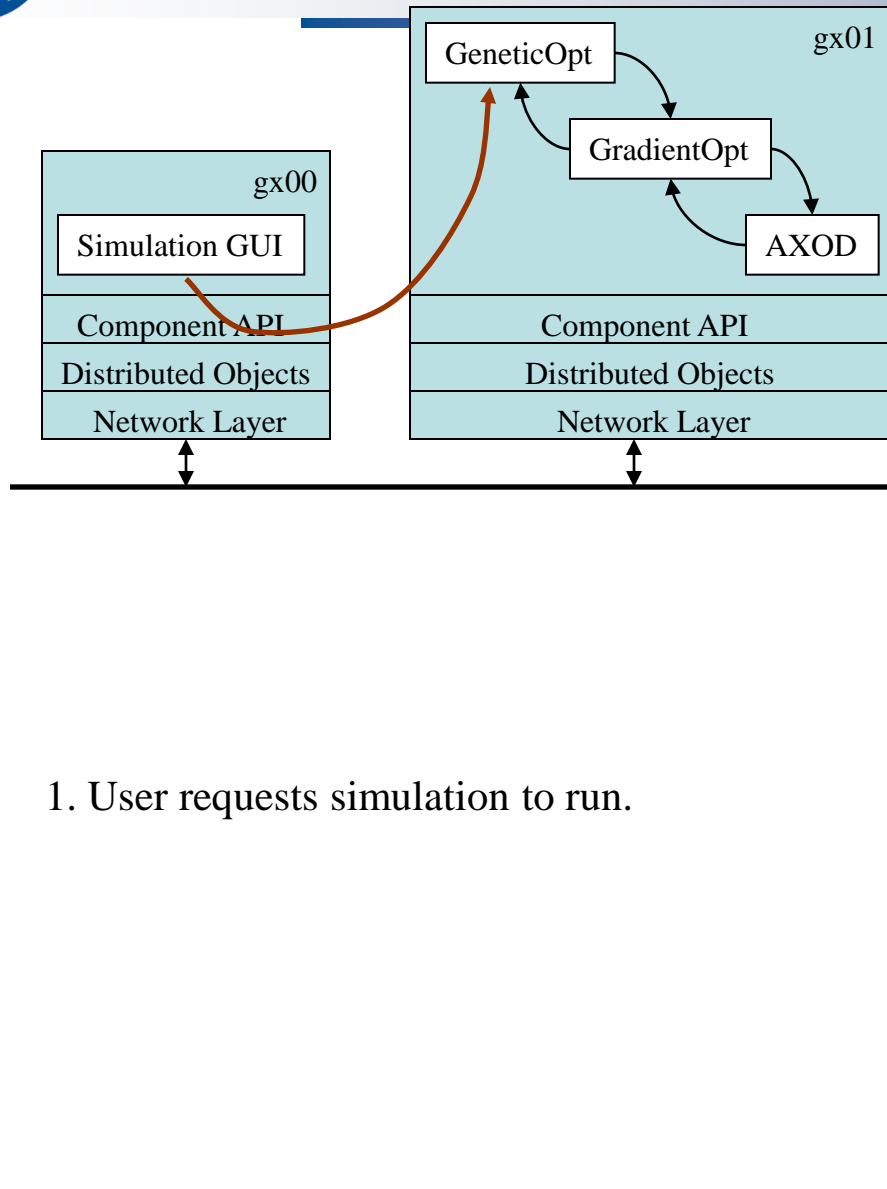
Outreach: NRA and SBIR Activities

- **Subsonic Fixed Wing NRAs**
 - Develop parametric blade geometry modeler (AVETeC/University of Cincinnati)
 - "System Analysis & Design Approach to the Hybrid Wing/Body Aircraft" (AVID LLC)
 - Improve structural modeling, meshing and rapid grid morphing capabilities within Vehicle Sketch Pad (Cal Poly/Phoenix Integration/J R Gouldemans)
 - "Enhanced Modeling & Analysis for Emission Prediction" (Georgia Tech/ASDL)
 - "Adv Multidisciplinary Optimization Techniques for Efficient Subsonic Aircraft Design" (MIT/Stanford/Purdue/Boeing)
- **Supersonics NRAs**
 - "High Fidelity MDO: Software Infrastructure & Application to Supersonic Aircraft" (M4 Engineering/Phoenix Integration)
 - "Control of Boundary Representation Topology in MDAO" (MIT)
 - "Multifidelity Analysis and Design Methods for Supersonic Aircraft" (Stanford/MIT)
- **Subsonic Fixed Wing SBIRs**
 - Cumulative Metamodelingw/Uncertainty Estimation (Nielsen Engineering)
 - Advanced Modeling Concepts for Conceptual Design (NextGenAeronautics)
 - Multidisciplinary Optimization Object Library (M4 Engineering)
 - Multi-Disciplinary, Multi-Fidelity Design Environment (Phoenix Integration)

Details on any NRA & SBIR efforts are available.



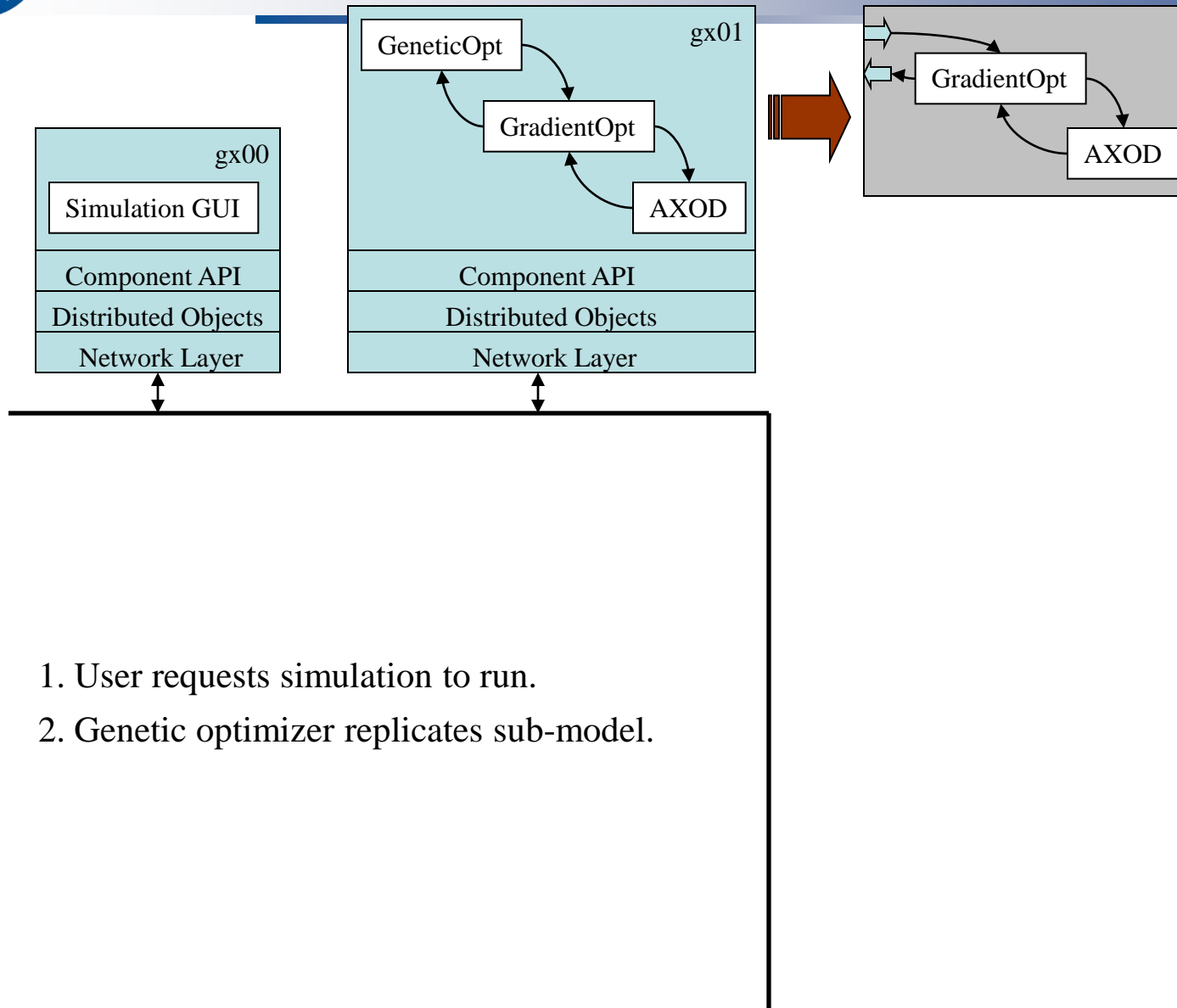
Example: Optimization Using a Cluster



1. User requests simulation to run.

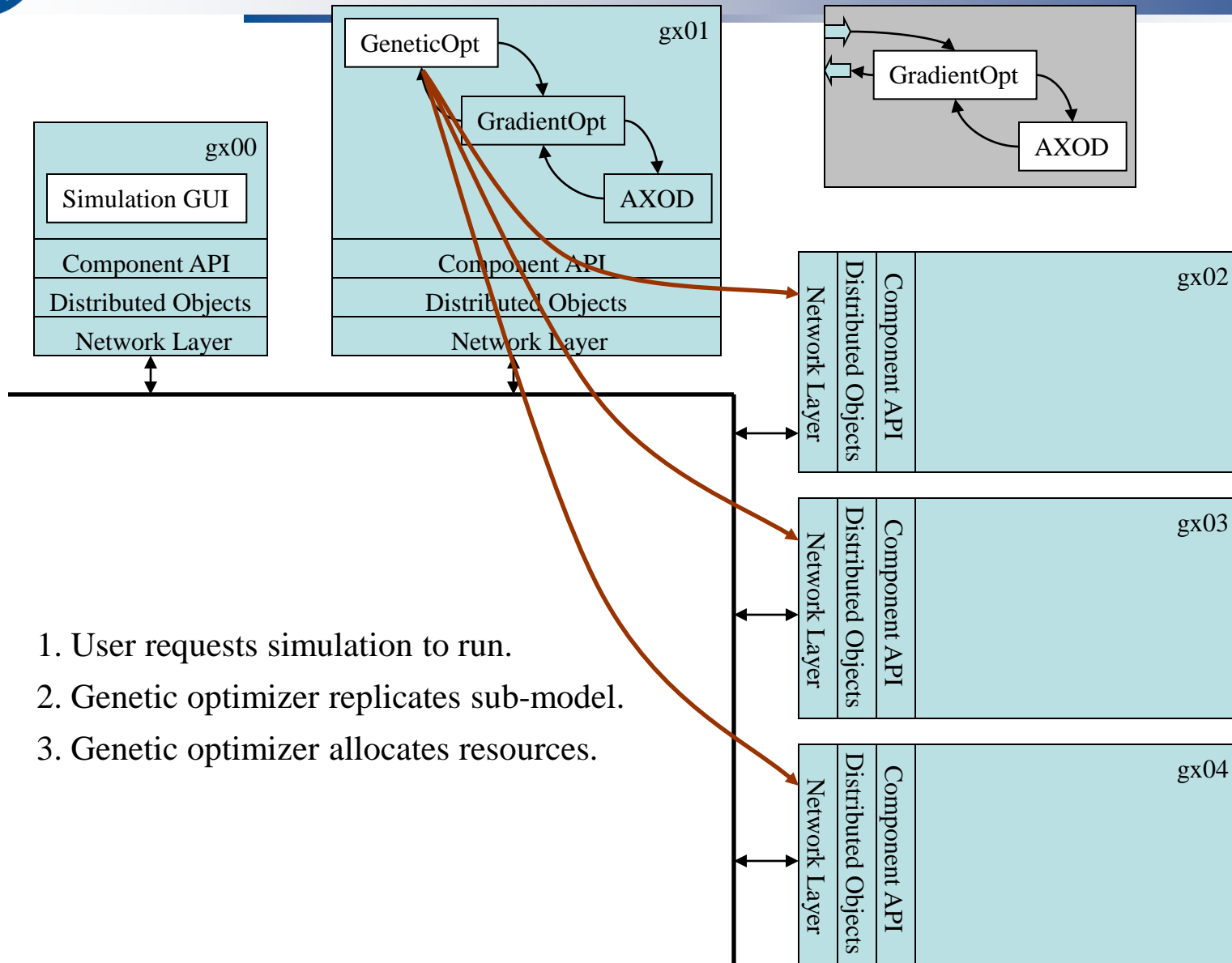


Example: Optimization Using a Cluster



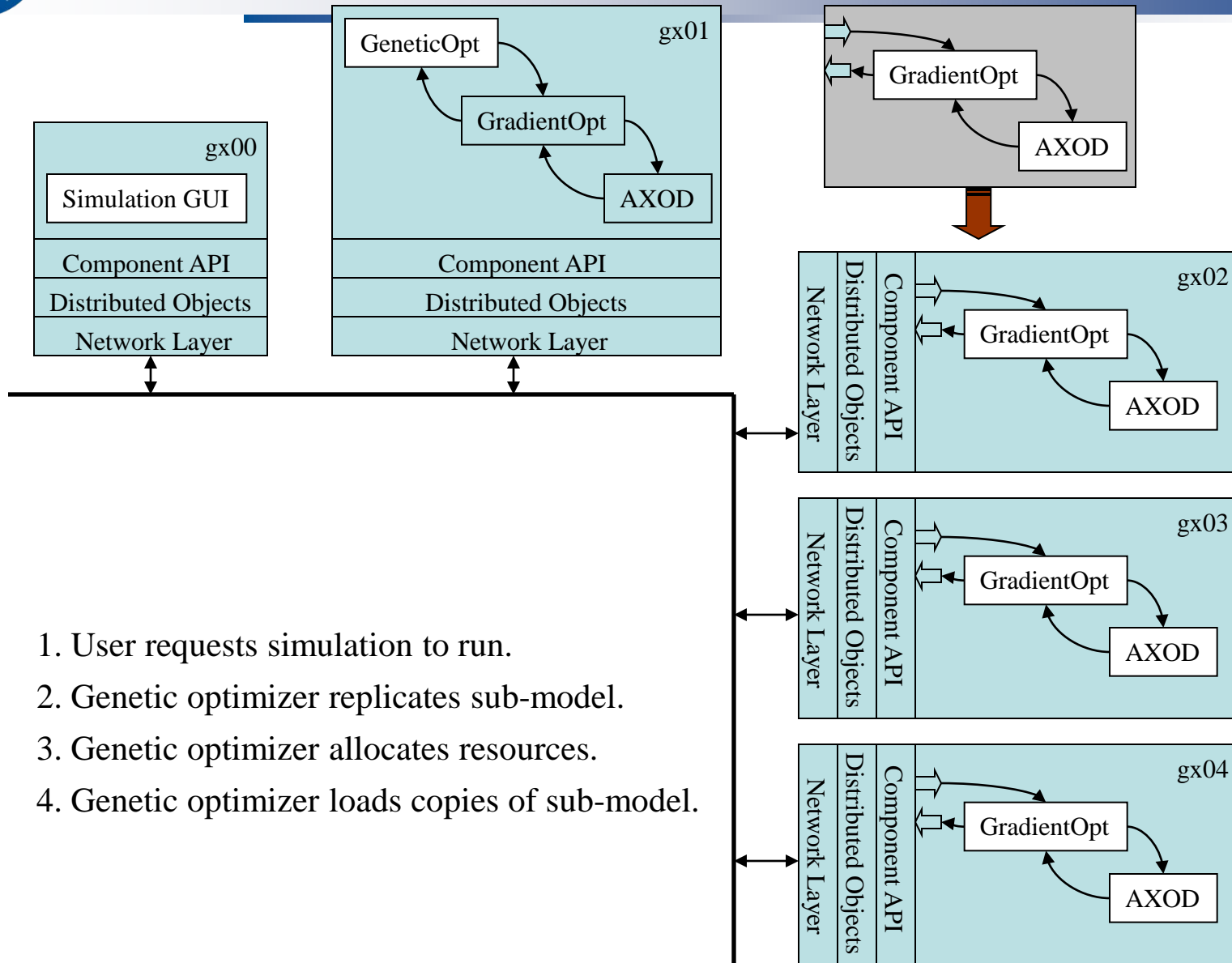


Example: Optimization Using a Cluster



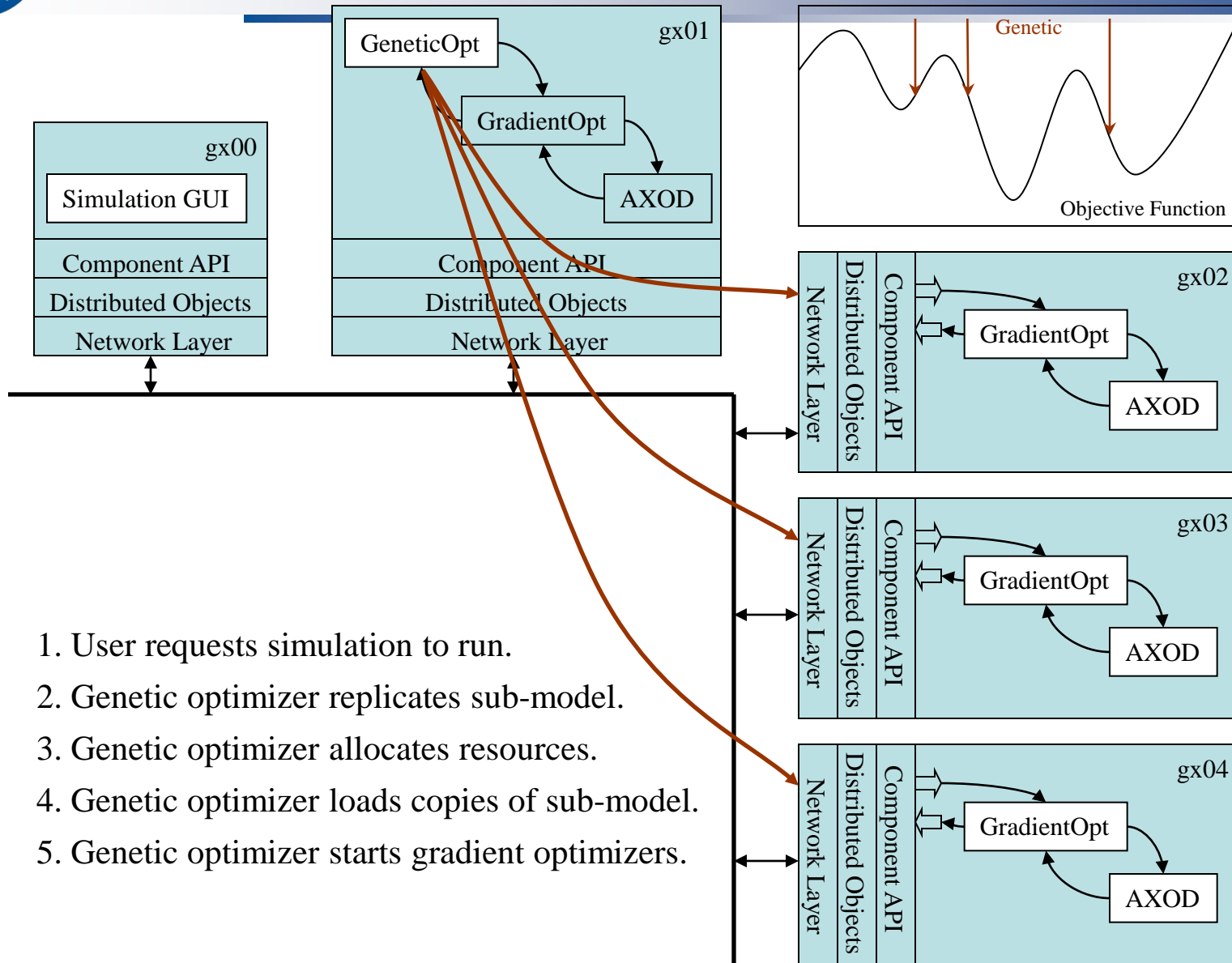


Example: Optimization Using a Cluster



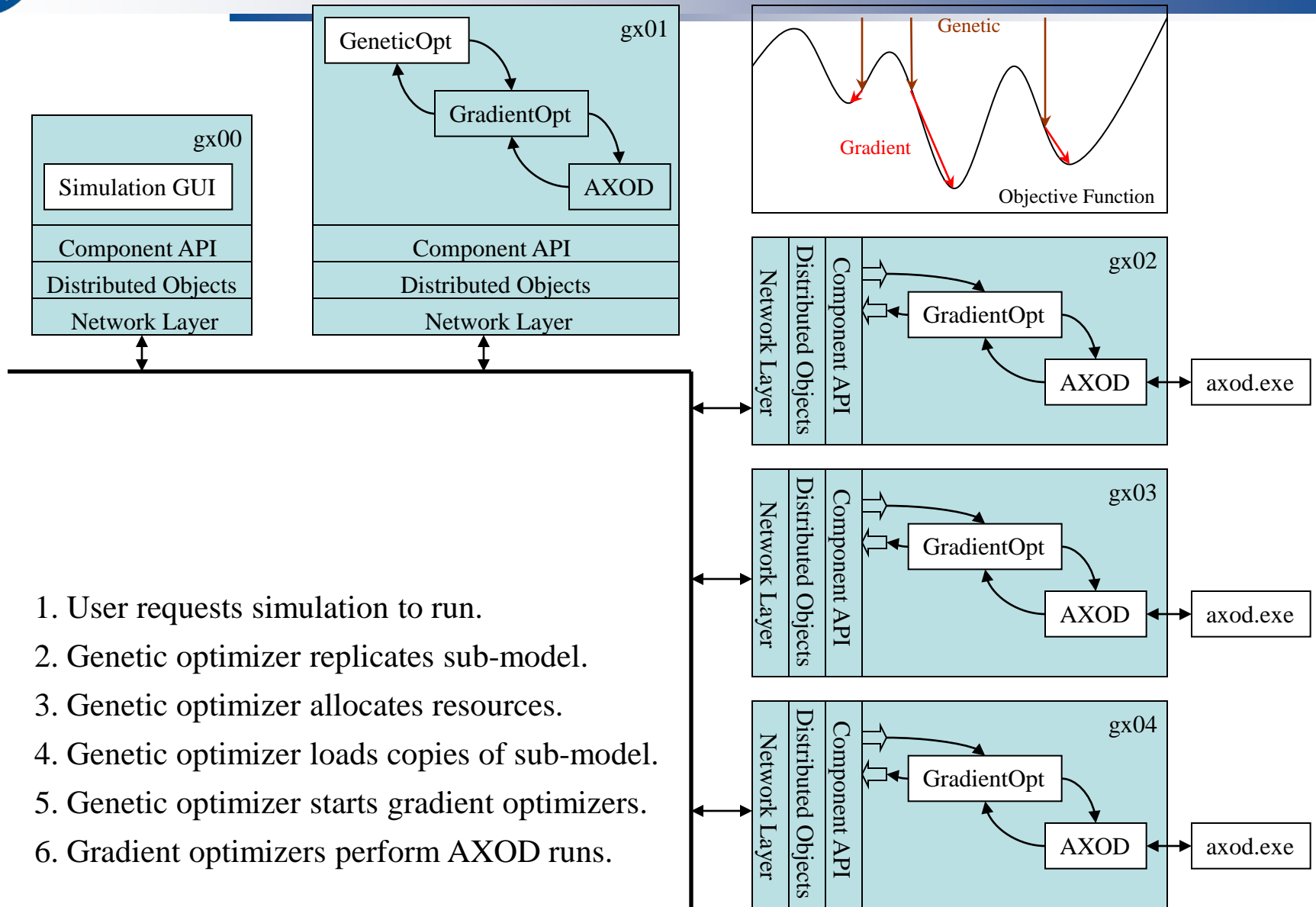


Example: Optimization Using a Cluster



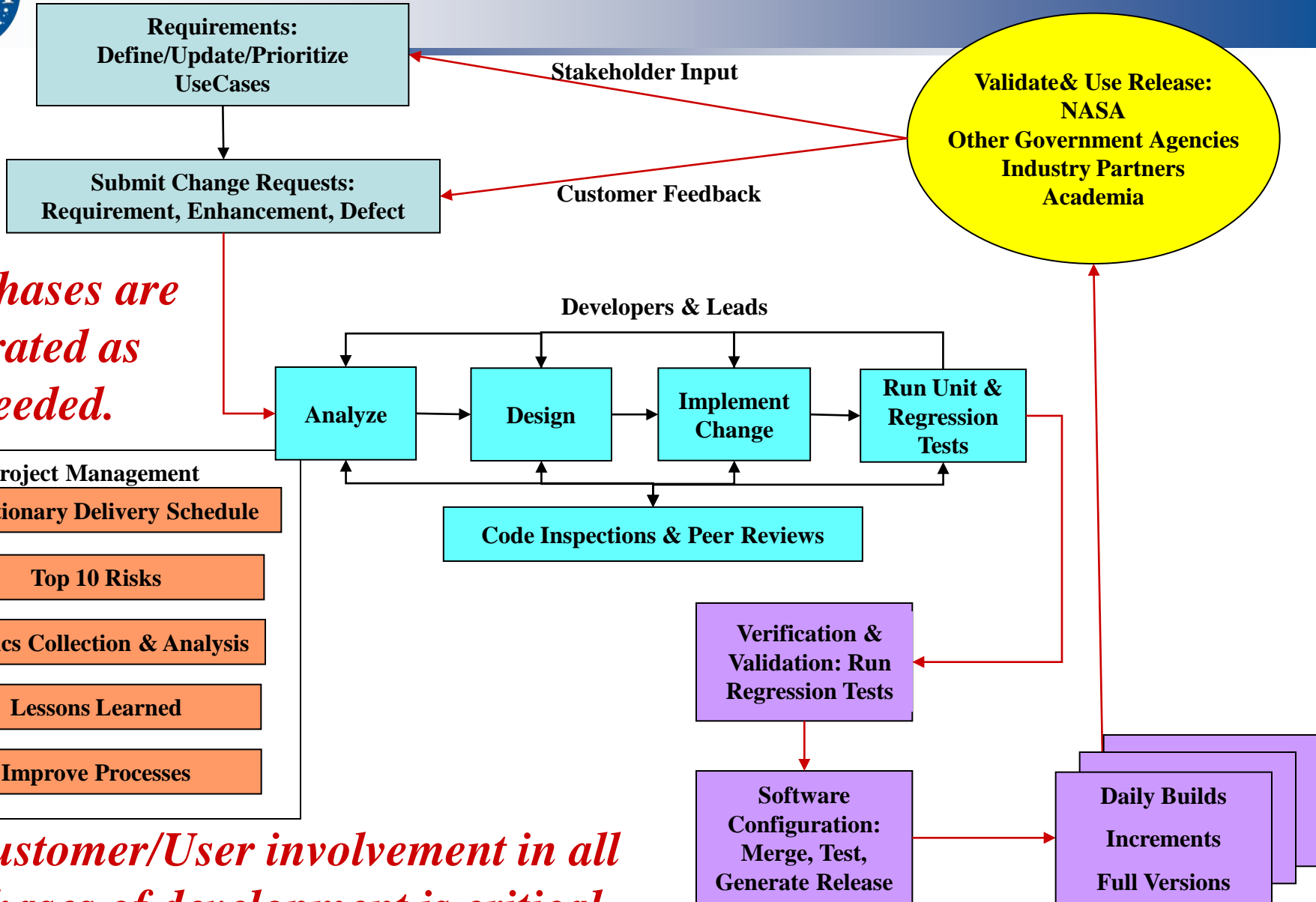


Example: Optimization Using a Cluster





Incremental Software Development



All phases are iterated as needed.

Customer/User involvement in all phases of development is critical.